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FIG. 1

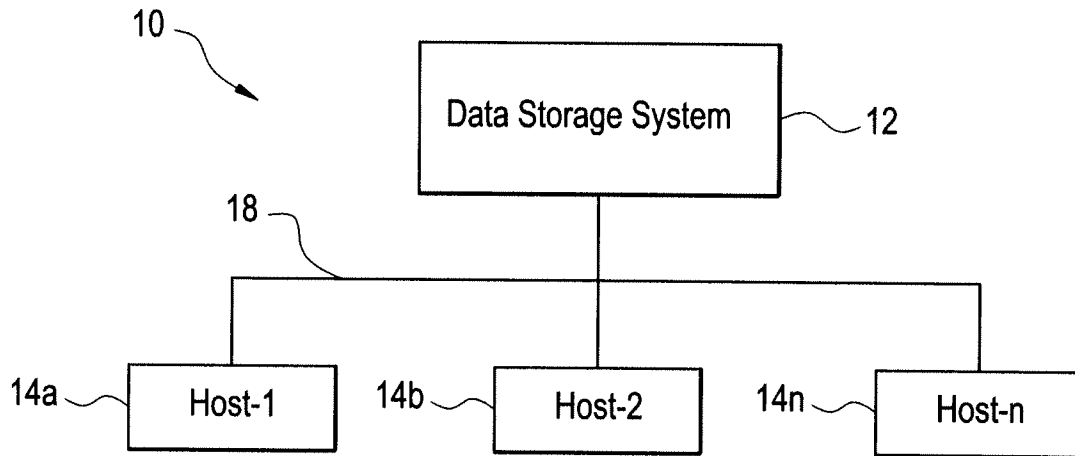


FIG. 2

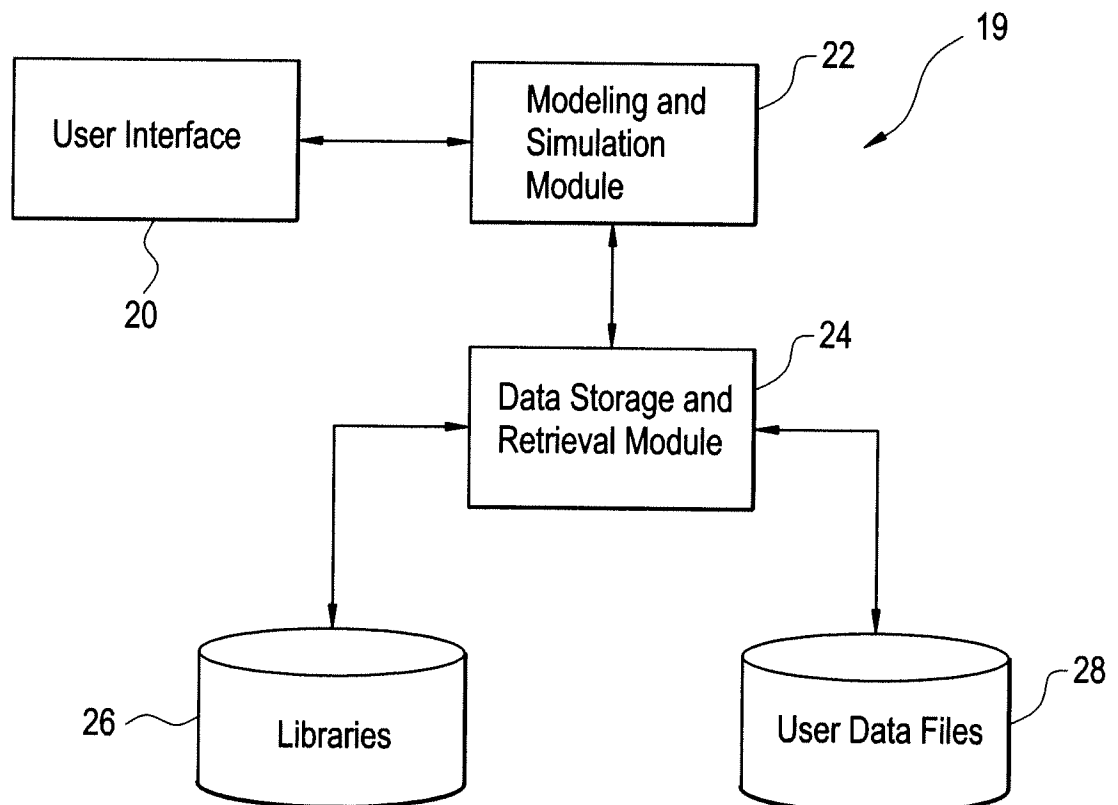
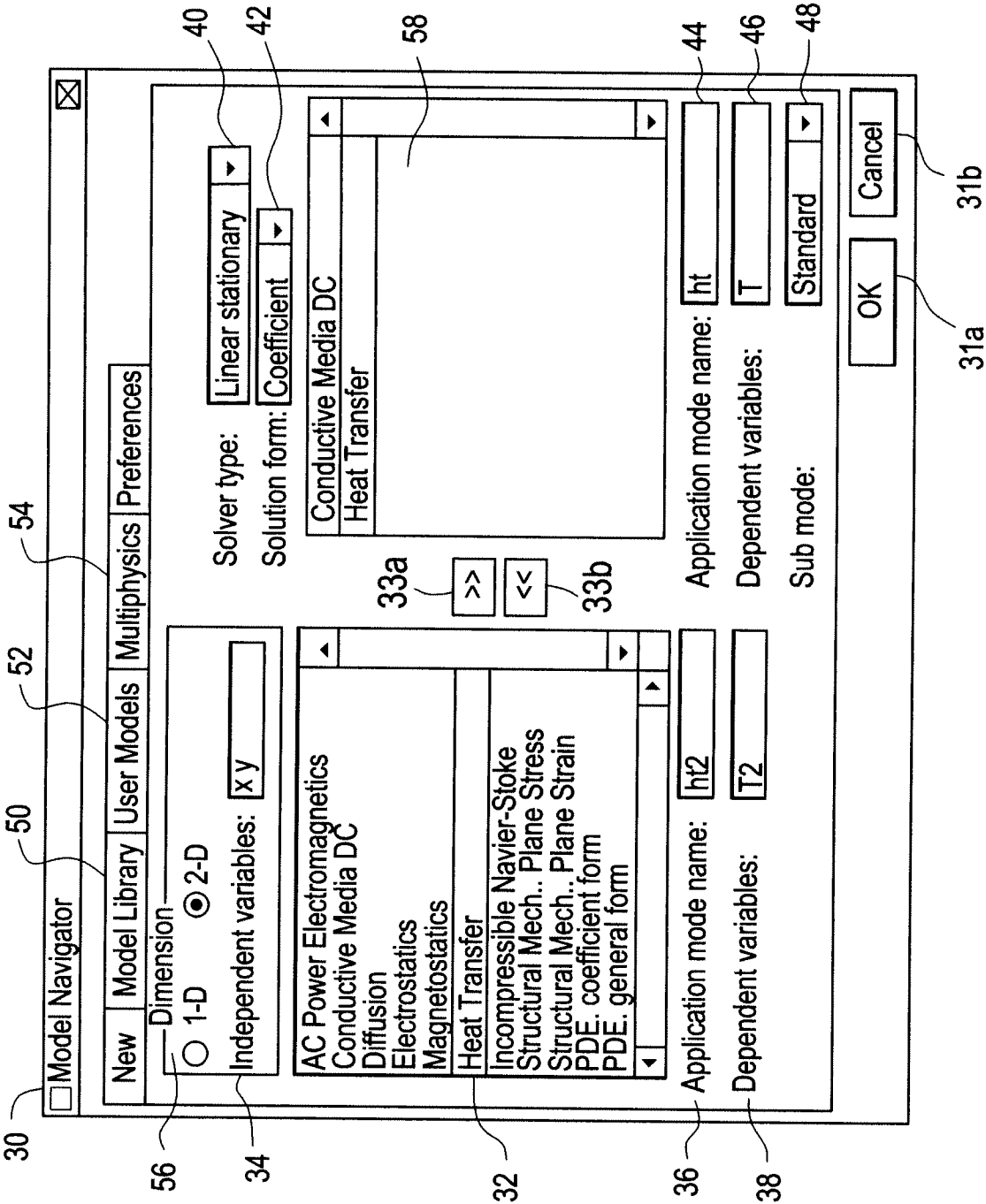


FIG. 3



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FIG. 4

☐ PDE Specification/ht

Equation: $p \cdot C \cdot T^i - V \cdot (kVT) = Q + h(T_{\text{ext}} \cdot T) + C_{\text{trans}} \cdot (T^4_{\text{ambtrans}} \cdot T^4)$. T = temperature

Subdomain selection

1

Name 1

☒ Active in the subdomain

PDE coefficients

☒ Unlock

64a

Coefficient	Value	Description
p	8930	Density
C	340	Heat capacity
k	384	Coeff. of heat conduction
Q	$1/(0*(1+\alpha*(T-T_0)))^i$	Heat source
h _{trans}	0	Convect. heat transf. coeff.
T _{ext}	0	External temperature
C _{trans}	0	User defined constant
T _{ambtrans}	0	Ambient temperature

☒ On top

OK

Cancel

Apply

64

60

62

62a

66

64a

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FIG. 5

70

☐ Boundary Conditions/ht

Equation: $T = T_0$

Boundary selection

72

1 2 3 4 5 6 7

Name: 1

72b

☐ Enable borders

72a

74a

Boundary coefficients ☒ Unlock

Quantity	Value	Description
<input type="radio"/> q	0	Heat flux
<input type="radio"/> h	0	Heat transfer coefficient
<input type="radio"/> T _{inf}	0	External temperature
<input type="radio"/> C	0	Problem-dependent constant
<input type="radio"/> T _{amb}	0	Ambient temperature
<input type="radio"/> $n \cdot (k \cdot \text{grad} T) = 0$		Insulation/symmetry
<input checked="" type="radio"/> T	300	Temperature
<input type="radio"/> T=0		Zero temperature

74

74b

☒ On top

OK Cancel Apply

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FIG. 6

Boundary Conditions/Coefficient View

Equation: $n \cdot (cVu + \alpha u - T) + q \cdot u = g \cdot h \cdot \lambda; h \cdot u = r$

q

g

h

r

$82a$

$82b$

$82c$

$82d$

$84a$

$84b$

$84c$

$84d$

Boundary selection

1

2

3

4

Name:

q coefficient

u	v	T	ps
1	0	0	ps
0	1	0	ht
0	0	0	

☐ On top

OK

Cancel

Apply

80

88

96

94

92a

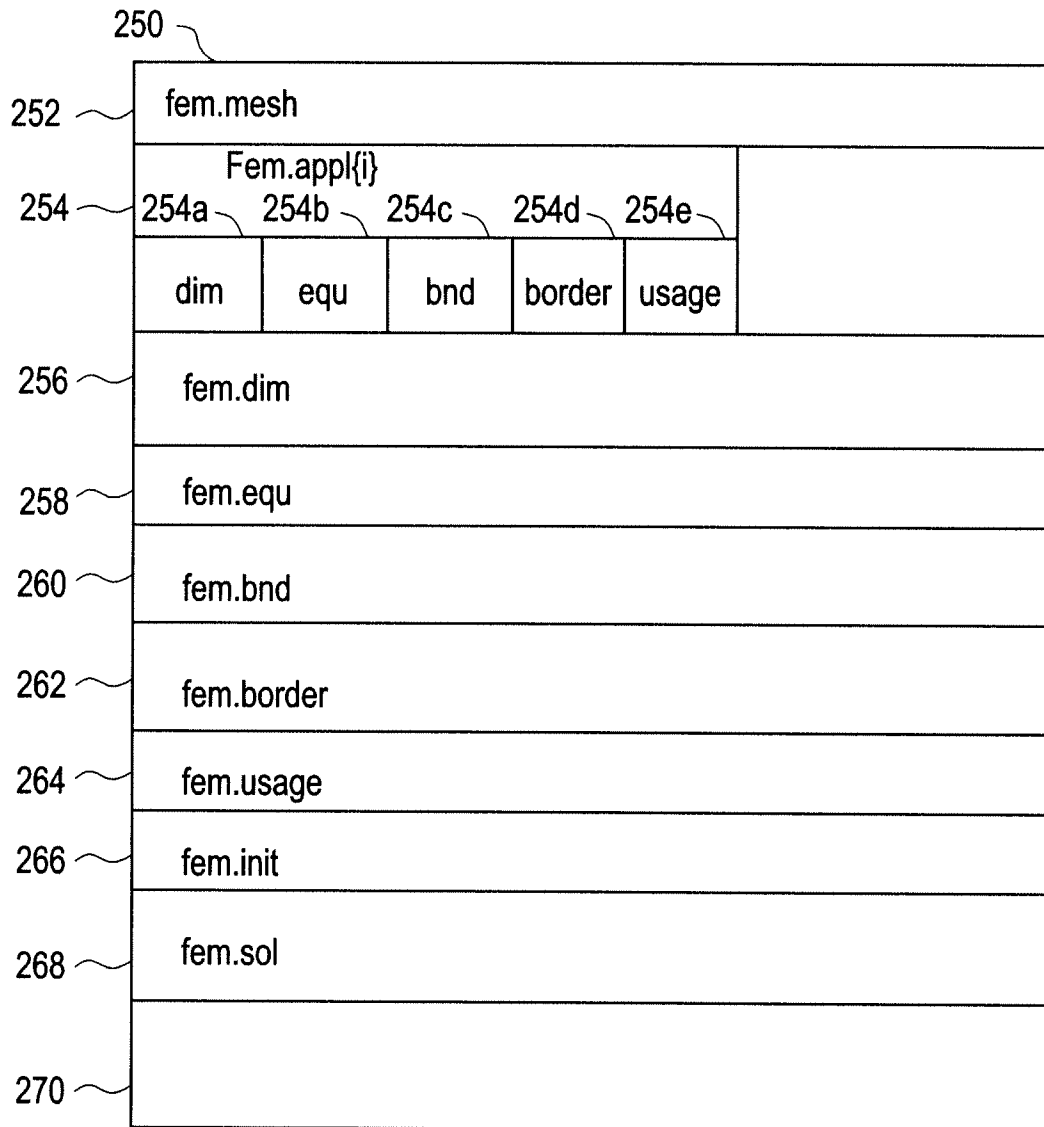
92b

92c

90

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FIG. 6A



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FIG. 7

110

☐ Solver Parameters

112

General Adaption Nonlinear Timestepping Eigenvalue Multigrid Multiphysics

114a

☐ Solve for variables

☐ Show variables

114

Structural Mechanics, Plane Stress (ps)
Heat Transfer (ht)

116

Update mechanism for initial value u

116a

☐ Update u

116b

☐ Update u automatically

116c

☐ Use interpolation

116d

Use solution number 1

118a

Solve

118b

OK

118c

Cancel

118d

Apply

$$150 \left\{ \begin{array}{l} d_a l k \frac{\partial u_k}{\partial t} + \frac{\partial \Gamma l j}{\partial x_j} = F_l \\ -n_j \Gamma l j = G l + \frac{\partial R_m}{\partial u_l} \lambda_m \\ 0 = R_m \end{array} \right. \quad \left. \begin{array}{l} \Omega \} 152 \\ \partial \Omega \} 154a \\ \partial \Omega \} 154b \end{array} \right\} 154$$

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FIG. 10

$$324 \left\{ \begin{array}{ll} \gamma_{lj} = \Gamma_{lj} & f_l = F_l \\ c_{lkji} = -\frac{\partial \Gamma_{lj}}{\partial \left(\frac{\partial u_k}{\partial x_i} \right)} & \alpha_{lkj} = -\frac{\partial \Gamma_{lj}}{\partial u_k} \\ \beta_{lki} = -\frac{\partial F_l}{\partial \left(\frac{\partial u_k}{\partial x_i} \right)} & a_{lk} = -\frac{\partial F_l}{\partial u_k} \\ g_l = G_l & r_l = R_l \\ q_{lk} = -\frac{\partial G_l}{\partial u_k} & h_{lk} = -\frac{\partial R_l}{\partial u_k} \end{array} \right.$$

FIG. 11

$$240 \left\{ \begin{array}{l} \Gamma_{lj} = c_{lkji} \frac{\partial u_k}{\partial x_i} \alpha_{lkj} u_k + \gamma_{lj} \\ F_l = f_l - \beta_{lki} a_{lk} u_k \\ G_l = g_l - q_{lk} u_k \\ R_m = r_m - h_{ml} u_l \end{array} \right.$$

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FIG. 12

$$300 \left\{ \begin{array}{l} \int_{\Omega} \left(\left(c_{lkji} \frac{\partial u_k}{\partial x_i} + \alpha_{lkj} u_k \right) \frac{\partial v}{\partial x_j} + \left(d_{alk} \frac{\partial u_k}{\partial t} + \beta_{lki} \frac{\partial u_k}{\partial x_i} + a_{lk} u_k \right) v \right) dx + \\ \int_{\partial \Omega} q_{lk} u_k v ds = \int_{\Omega} \left(Y_{lj} \frac{\partial v}{\partial x_j} + f_l v \right) dx + \int_{\partial \Omega} (g_l - h_{ml} \lambda_m) v ds \\ \int_{\partial \Omega} \mu h_{mk} u_k ds = \int_{\partial \Omega} \mu r_m ds \end{array} \right.$$

FIG. 13

$$302 \left\{ \begin{array}{l} \int_{\Omega} \left(\Gamma_{lj} \frac{\partial v}{\partial x_j} + F_l v - d_{alk} \frac{\partial u_k}{\partial t} v \right) dx + \int_{\partial \Omega} \left(G_l + \frac{\partial R_m}{\partial u_l} \lambda_m \right) v ds = 0 \\ \int_{\partial \Omega} R_m \mu ds = 0 \end{array} \right.$$

FIG. 14

$$304 \left\{ \begin{array}{l} U_k(x) = \sum_{l=1}^{N_p} U_{l,k} \phi_l(x), \quad \Lambda_m(x) = \sum_{K=1}^N \sum_{L=1}^n \Lambda_{K,L,m} \Psi_{K,L}(x) \end{array} \right.$$

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FIG. 15

$$306 \left\{ \begin{aligned} & \int_{\tau} \left(c_{lkji} U_{l,k} \frac{\partial \phi_I}{\partial x_i} + \alpha_{lkj} U_{l,k} \phi_I \right) \frac{\partial \phi_J}{\partial x_j} dx + \\ & \int_{\tau} \left(d_{alk} \frac{\partial U}{\partial I} I_{,k} \phi_i + \beta_{lkj} U_{i,k} \frac{\partial \phi_I}{\partial x_I} + \alpha_{lk} U_{i,k} \phi_i \right) \phi_J dx + \\ & \int_{\partial \tau} q_{lk} U_{l,k} \phi_I \phi_J ds = \int_{\tau} \left(\gamma_{Ij} \frac{\partial \phi_J}{\partial x_j} + f_I \phi_J \right) dx + \\ & \int_{\partial \tau} (g_I - h_{mI} \Lambda_{K,L,m} \Psi_{K,L}) \phi_J ds \end{aligned} \right.$$

FIG. 16

$$308 \left\{ \begin{aligned} & \int_{\partial \tau} h_{mk} U_{J,k} \phi_I \Psi_{K,L} ds = \int_{\partial \tau} r_m \Psi_{K,L} ds \end{aligned} \right.$$

FIG. 17

$$312 \left\{ \begin{aligned} & \int_{\tau} \left(\Gamma_{lj} \frac{\partial \phi_J}{\partial x_j} + F_I \phi_J - \alpha_{lk} \frac{\partial u_k}{\partial I} \phi_J \right) dx + \int_{\partial \tau} \left(G_I + \frac{\partial R_m}{\partial u_I} \Lambda_{K,L,m} \Psi_{K,L} \right) \phi_J ds = 0 \\ & \int_{\partial \tau} R_m \Psi_{K,L} ds = 0 \end{aligned} \right.$$

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FIG. 18

$$\begin{aligned}
 & DA_{(J,l),(I,k)} = \int_{\tau} d_{alk} \phi_I \phi_J dx \\
 & C_{(J,l),(I,k)} = \int_{\tau} c_{lkji} \frac{\partial \phi_I}{\partial x_i} \frac{\partial \phi_J}{\partial x_j} dx \\
 & AL_{(J,l),(I,k)} = \int_{\tau} \alpha_{lkj} \phi_I \frac{\partial \phi_J}{\partial x_j} dx \\
 & BE_{(J,l),(I,k)} = \int_{\tau} \beta_{lki} \frac{\partial \phi_I}{\partial x_i} \phi_j dx \\
 & A_{(J,l),(I,k)} = \int_{\tau} a_{lk} \phi_I \phi_J dx \\
 & Q_{(J,l),(I,k)} = \int_{\tau} q_{lk} \phi_I \phi_J ds \\
 & GA_{(J,l)} = \int_{\tau} \gamma_{lj} \frac{\partial \phi_J}{\partial x_j} dx \\
 & F_{(J,l)} = \int_{\tau} f_I \phi_J dx \\
 & G_{(J,l)} = \int_{\partial \tau} g_I \phi_J ds \\
 & H_{(K,L,m),(I,k)} = \int_{\partial \tau} h_{mk} \phi_I \psi_{K,L} ds \\
 & R_{(K,L,m)} = \int_{\partial \tau} r_m \psi_{K,L} ds
 \end{aligned}$$

FIG. 19

$$\begin{aligned}
 & DA \frac{\partial U}{\partial t} + (C + AL + BE + A + Q) U + H^T \Lambda = GA + F + G \\
 & HU = R
 \end{aligned}$$

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FIG. 20

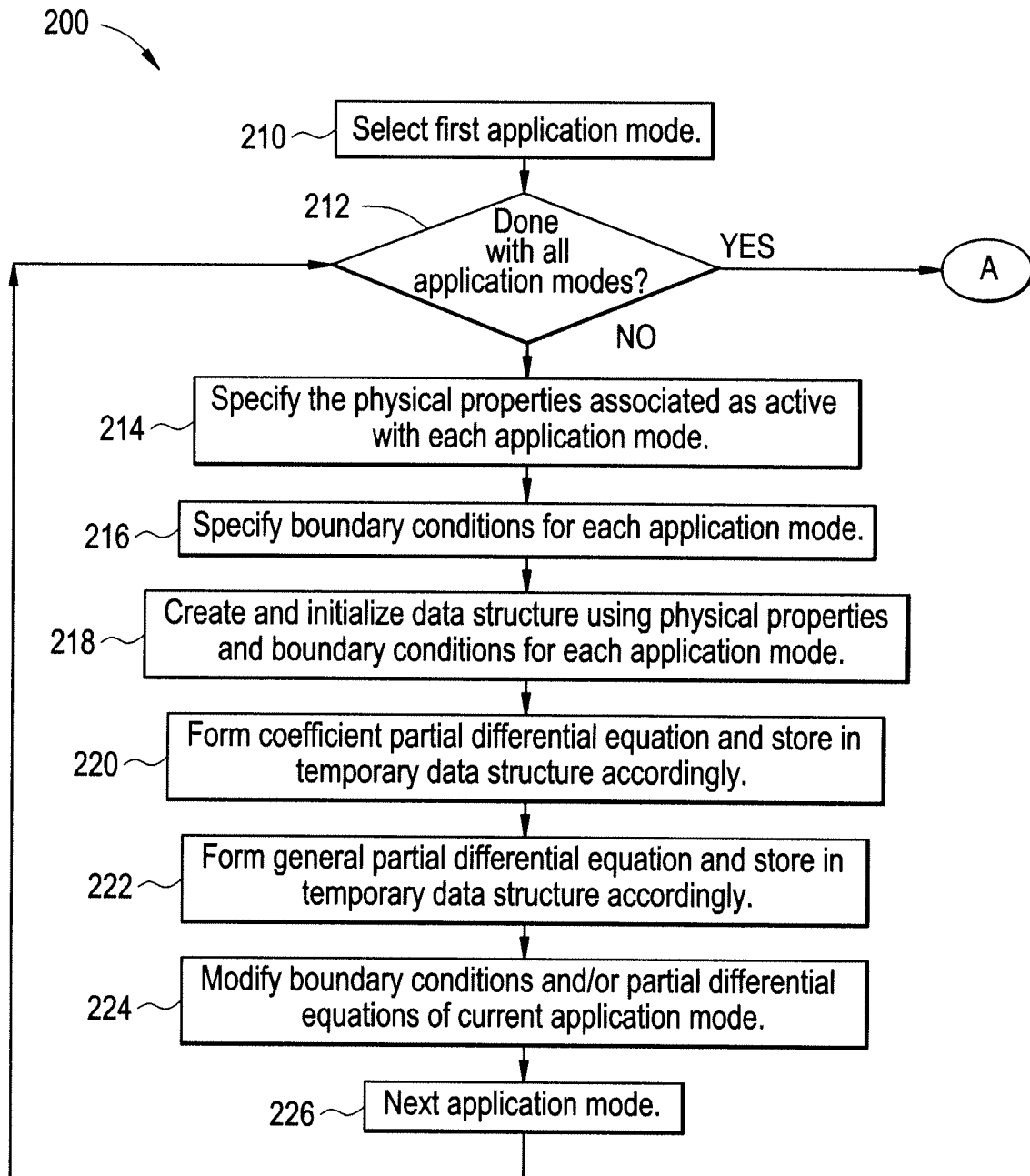
$$322 \left\{ \begin{array}{l} DA \frac{\partial U}{\partial t} + H^T \Lambda = GA + F + G \\ R = 0 \end{array} \right.$$

FIG. 21

$$322 \left\{ \begin{array}{l} J(U^{(k)}) \Delta U^{(k)} p(U^{(k)}) \\ U^{(k+1)} - U^{(k)} \lambda \Delta U^{(k)} \end{array} \right.$$

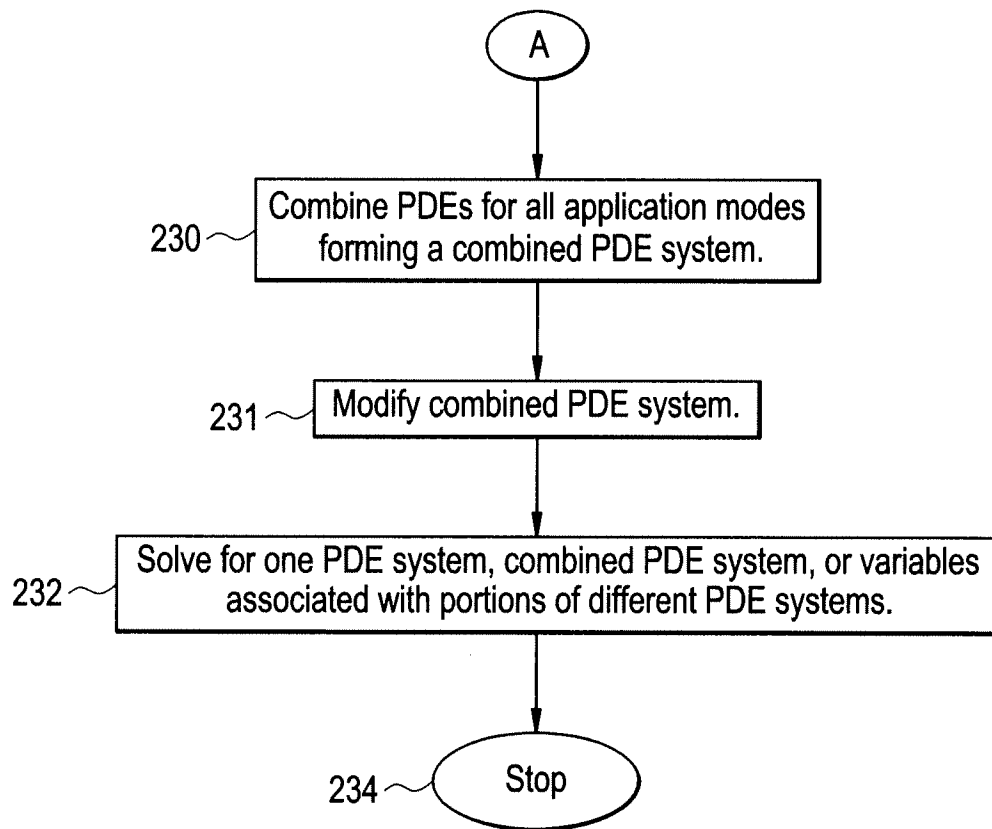
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FIG. 22



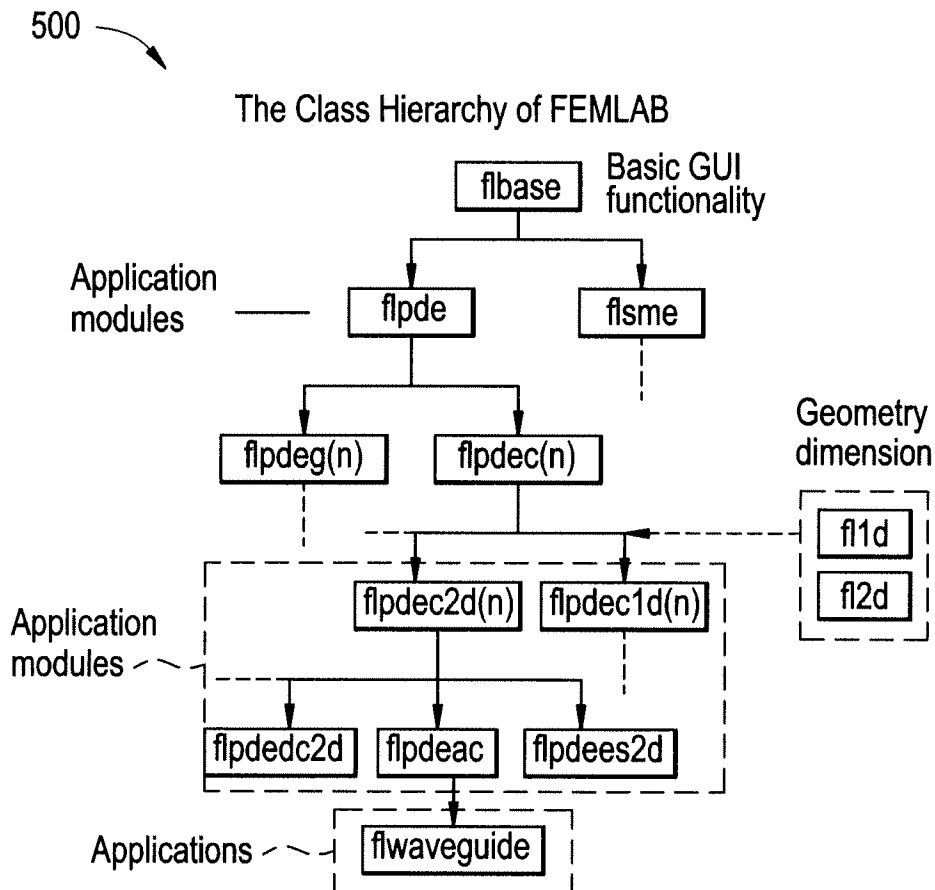
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FIG. 23



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FIG. 24



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FIG. 25

1-D Physics Application Modes			502
Application mode	Class name	Parent class	
Diffusion	flpdedf1d	flpdedf	
Heat Transfer	flpdeht1d	flpdeht	
1-D PDE Application Modes			504
Application mode	Class name	Parent class	
Coefficient PDE model, n variables	flpdec1d (n)	flpdec (n)	
General PDE model, n variables	flpdeg1d (n)	flpdeg (n)	

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FIG. 26

2-D Physics Application Modes

Application Mode	Class name	Parent class
AC Power Electromagnetics	flpdeac	flpdec2d
Conductive Media DC	flpdedc2d	flpdedc
Diffusion	flpdedf2d	flpdedf
Electrostatics	flpdees2d	flpdees
Magnetostatics	flpdems2d	flpdems
Heat Transfer	flpdeht2d	flpdeht
Incompressible Navier-Stokes	flpdens2d	flpdens
Structural Mechanics, Plane Stress	flpdeps	flpdec2d
Structural Mechanics, Plane Strain	flpdepn	flpdec2d
506		
PDE Application Modes		
Application Mode	Class name	Parent class
Coefficient PDE model, n variables	flpdec2d (n)	flpdec (n)
General PDE model, n variables	flpdeg2d (n)	flpdeg (n)
508		

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FIG. 27

Application Object Properties

Property name	Description	Data type	514
dim	Names of the dependent variables	Cell array of strings	
form	PDE form	String (coefficient/general)	
name	Application name	String	
parent	Parent class names	String. cell array of strings. or the empty matrix	
sdim	Names of the independent variables (space dimensions)	Cell array of stings	
submode	Name of current submode	String (std/wave)	
tdiff	Time differentiation flag	String (on/off)	

FIG. 28

512 {

```

function obj = myapp()
%MYAPP Constructor for a FEMLAB application object.

obj.name = 'My first FEMLAB application';
obj.parent = 'flpdeht2d';

% MYAPP is a subclass of FLPDEHT2D:

p1 = "flpdeht2d;
obj = class (obj, 'myapp' , p1);
set (obj , 'dim' , default_dim (obj));
  
```

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FIG. 29

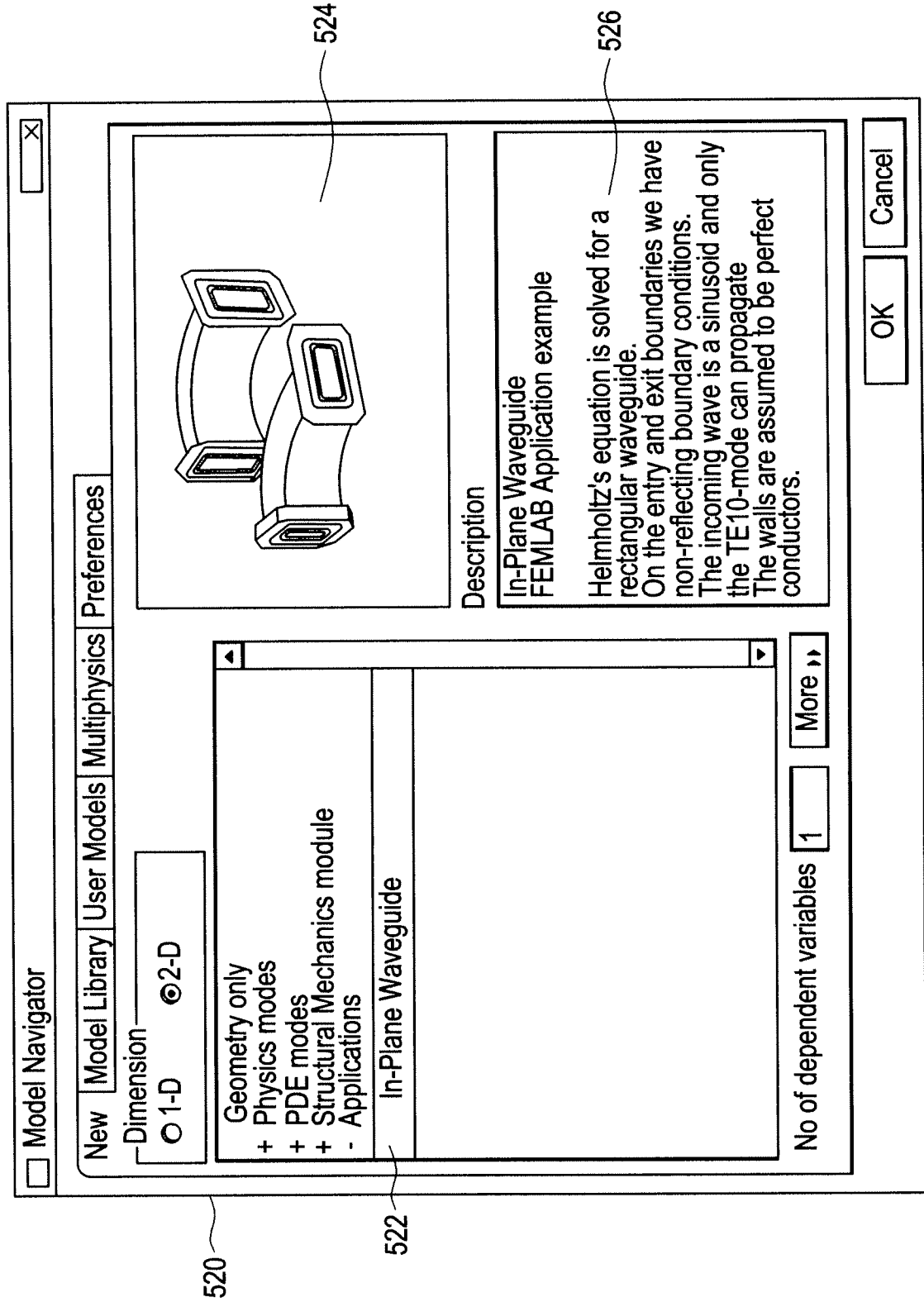
Physics Modeling Methods

514

Function	Purpose
appspect	Return application specifications.
bnd_compute	Convert application-dependent boundary conditins to generic boundary coefficents.
default_bnd	Default boundary conditions.
default_dim	Default names of dependent variables
default_equ	Default PDE coefficients/Material parameters.
default_init	Default initial conditions.
default_sdim	Default space dimension variables.
default_var	Default application scalar variables.
dim_compute	Return dependent variables for an application.
equ_compute	Convert application-dependent material parameters to generic PDE coefficients.
form_compute	Return PDE form.
init_compute	Convert application-dependent initial conditions to generic initial conditions
posttable	Define assigned variable names and post-processing information.

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FIG. 30



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FIG. 31

$$530 \left\{ \Delta E_Z + (2 \pi i k)^2 E_Z = 0 \right.$$

$$532 \left\{ k = \frac{1}{\lambda} = \frac{f}{c} \right.$$

$$534 \left\{ \bar{n} \cdot (\nabla E_Z) + 2 \pi i k_X E_Z = 4 \pi i k_X \sin \left(\frac{\pi}{d} (y - y_0) \right) \right.$$

$$536 \left\{ k^2 = k_X^2 + k_Y^2 \right.$$

$$538 \left\{ k_X = \sqrt{\frac{1}{\lambda^2} - \frac{1}{(2d)^2}} \right.$$

$$540 \left\{ n \cdot (\nabla E_Z) + 2 \pi i k_X E_Z = 0 \right.$$

$$542 \left\{ E_Z = 0 \right.$$

$$544 \left\{ f_c = \frac{c}{2d} \right.$$

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FIG. 32

550 {
function obj = flwaveguid (varargin)
%FLWAVEGUIDE Constructor for a waveguide application object.

obj. name = 'In-Plane Waveguide';
obj. parent = 'flpdeac';

% FLWAVEGUIDE is a subclass of FLPDEAC:
p1 = flpdeac;
obj = class (obj), 'flwaveguide' ,p1);
set (obj), 'dim' , default_dim(obj));

FIG. 33

552 {

fem.user fields	
Field	Description
geomparam	1-by-2 structure of geometry parameters.
entrybnd	Index to the entry boundary
exitbnd	Index to the exit boundary
freqs	Frequency vector

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FIG. 34

554	fem.user fields	
	Field	Description
	startpt	Index of the lower left corner point of the waveguide.
	type	Type of waveguide. (<i>straight</i> or <i>elbow</i>)

FIG. 35

geomparam fields

556	Field	Description	Defaults for elbow	Defaults for straight
	entrylength	Length of the entrance part of the waveguide.	0.1	0.1
	exitlength	Length of the exit part of the waveguide.	0.1	Not used
	radius	Outer radius of the waveguide bend.	0.05	Not used
	width	Width of the waveguide.	0.025	0.025
	cavityflag	Turn resonance cavity <i>on</i> or <i>off</i>	0	0
	cavitywidth	Width of the resonance cavity	0.025	0.025
	postwidth	Width of the protruding posts.	0.005	0.005
	postdepth	Depth of the protruding posts.	0.005	0.005